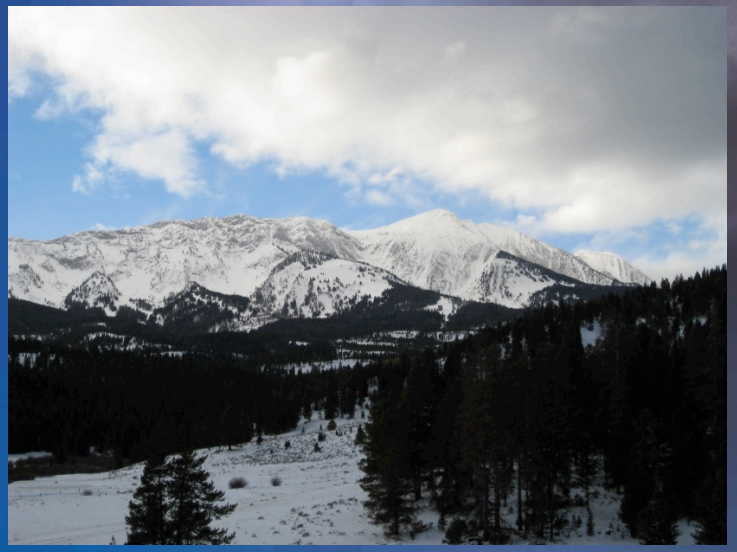
Heavy Snowfall Pattern Recognition for Bozeman, Montana

Megan L. Syner

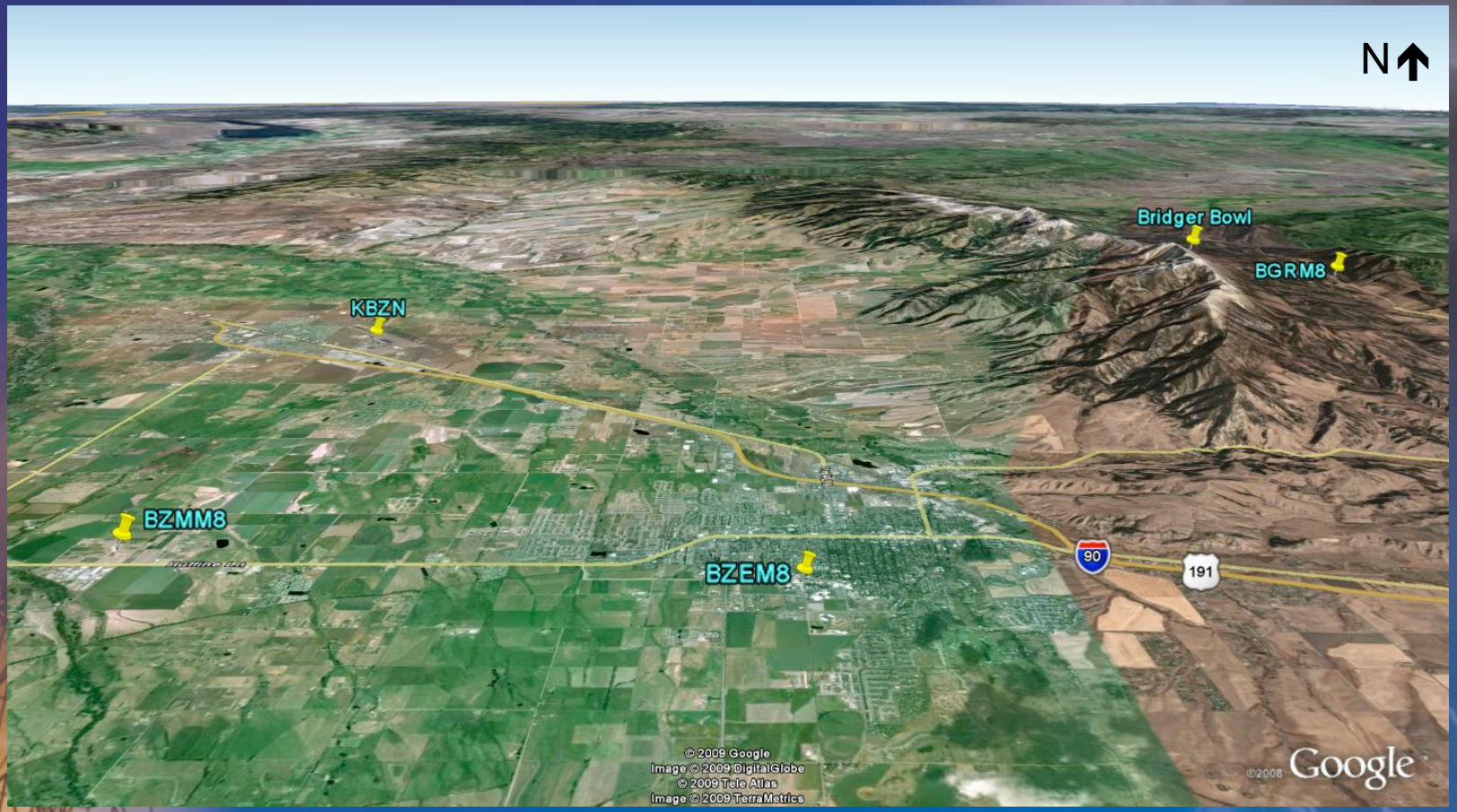
NWS Great Falls

Initial Procedures

- Selected 50 two-day heavy snowfall events between December – March for the period 1968 to 1995
  - *After 1995 KBZN no longer reported snowfall*
- For pattern recognition, focused primarily on height and pressure features
  - *Analyzed 4-panel NCEP Reanalysis maps*
  - *Specific emphasis on 500mb, 700mb and 850mb charts*
- Data sampling issues due to spatial and temporal variability



Observation Points

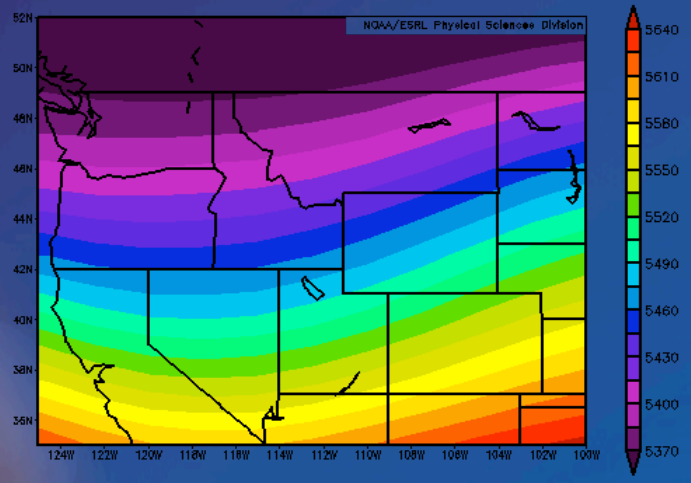


Name	KBZN8	BZMM8	BZEM8	BGRM8	Bridger Bowl
Elevation	4490’	4775’	4913’	5950’	7370’

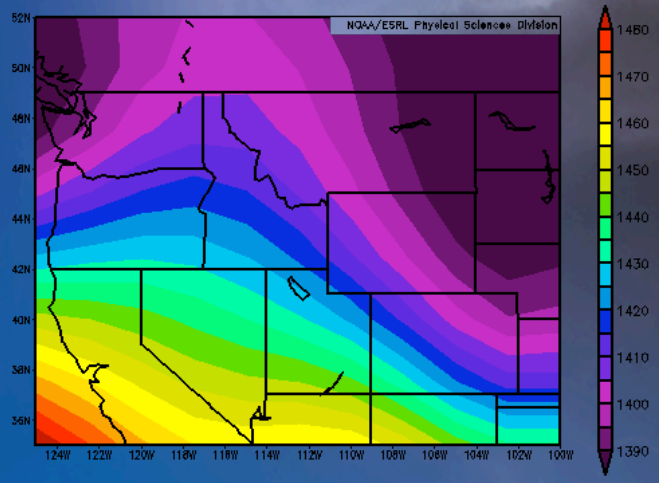
Initial Findings

- Found five common patterns
- Belgrade/Bozeman airport (KBZN) commonly received more snowfall under southwest flow
- Bridger Bowl received more snowfall with strong northwest flow
- Approximately 60% or 30 out of 50 sampled snowfall events at MSU-Bozeman (BZEM8) received twice the snowfall compared to the Belgrade/Bozeman airport

Pattern 1



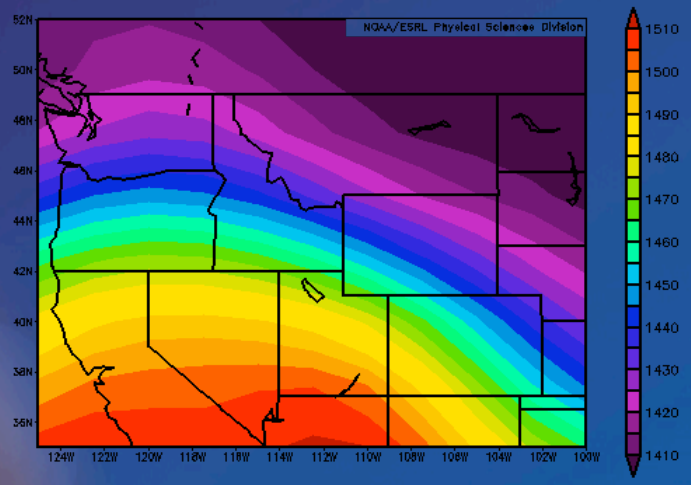
500mb



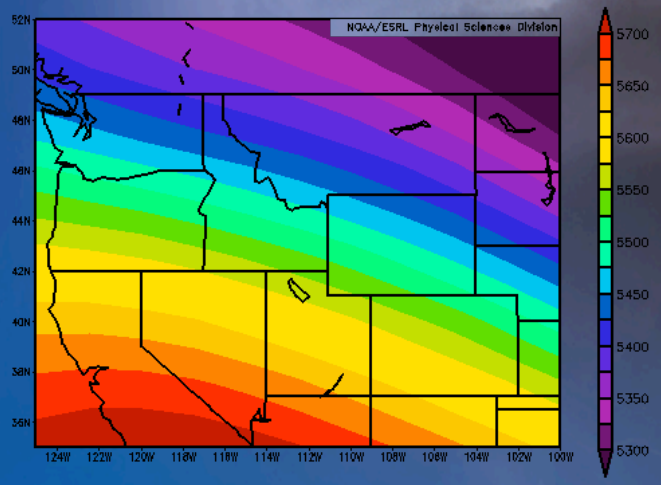
850mb

- Out of 50 cases, 16 or 32% fit into this pattern
- Predominant southwest flow aloft
- Low developing off of Pacific Northwest with deepening trough over the Intermountain West
- Canadian high pressure building south into Montana

Pattern 2



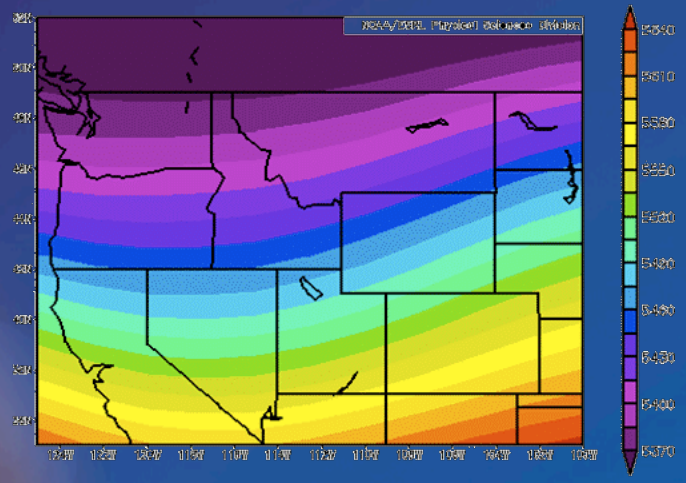
500mb



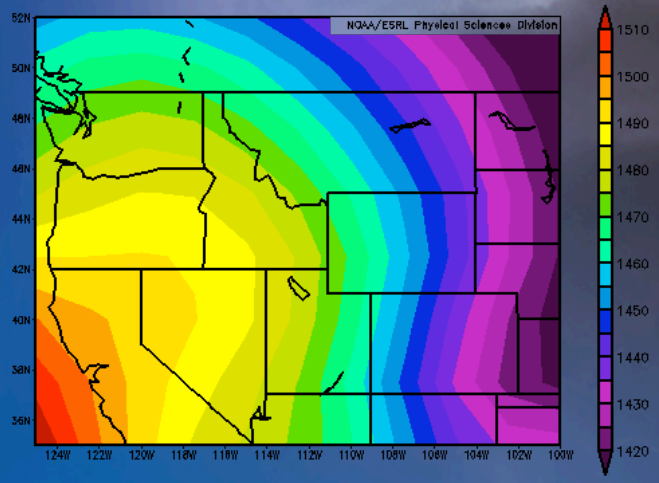
850mb

- Out of 50 cases, 7 or 14% fit into this pattern
- Predominant west and northwest flow aloft
- Low-level shortwave present near southwest Montana

Pattern 3



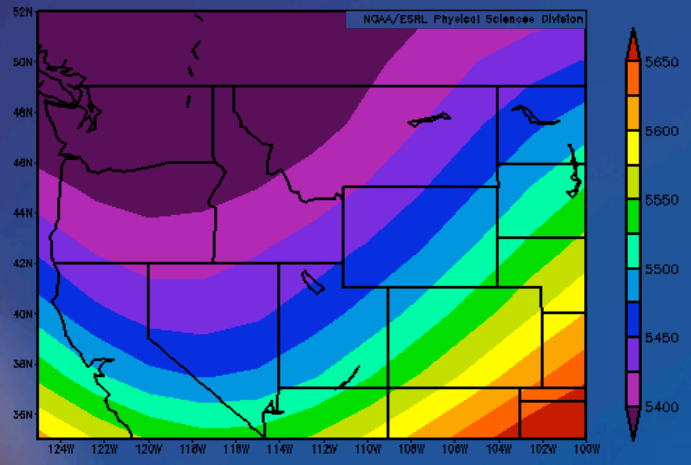
500mb



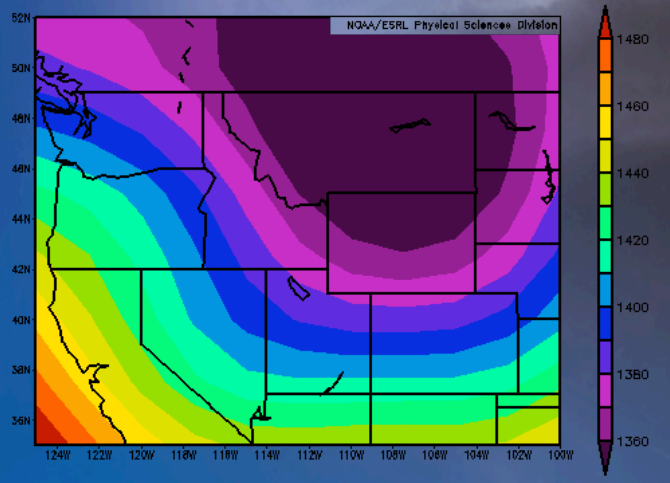
850mb

- Out of 50 cases, 9 or 18% fit into this pattern
- Southwest flow aloft becomes northwest as shortwave energy propagates through Pacific Northwest
- Canadian high pressure building south into Montana

Pattern 4



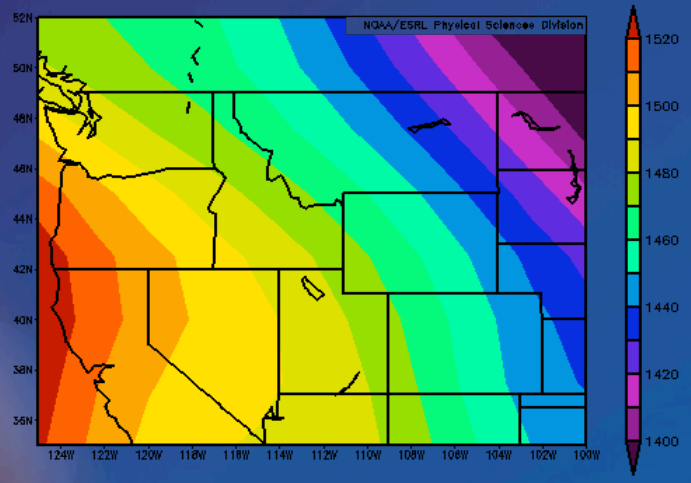
500mb



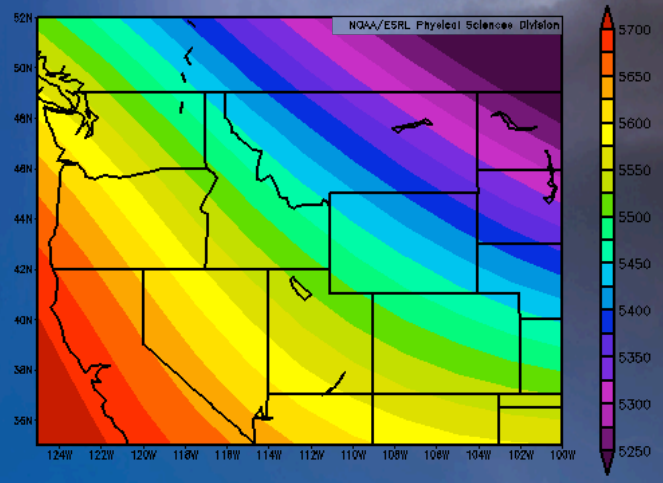
850mb

- Out of 50 cases, 7 or 14% fit into this pattern
- Predominant south-southwest flow aloft
- Deep trough over Western U.S.
- Quasi-closed lows present over southern Montana

Pattern 5



500mb



850mb

- Out of 50 cases, 11 or 22% fit into this pattern
- Predominant northwest flow aloft
- Strong ridge off of Pacific Coast
- Best pattern for heavy snow in Bridger Bowl?

Secondary Procedures/Challenges

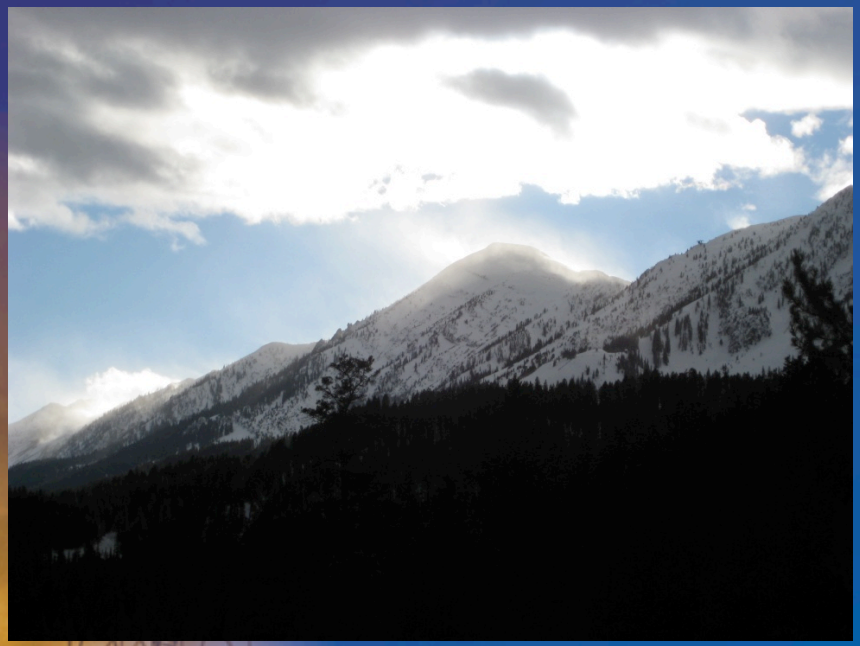
- Used same cases as in the initial procedures
- Emphasis placed on wind data
  - *Analyzed extracted data from the NCDC/FSL Radiosonde Data for North America CDROMs*
    - http://vortex.plymouth.edu/upairwx-r.html
  - *Specific emphasis on 500mb, 700mb and 850mb charts from Reanalysis Data*
    - http://www.esrl.noaa.gov/psd/data/composites/day/
- Data sampling issues due to spatial and temporal variability

Secondary Results

	500 mb	700 mb	850 mb
Pattern 1	• W/SW flow	• W/SW flow	• W/SW flow
Pattern 2	• W/NW flow	• W/NW flow	• W/NW flow
Pattern 3	• W/SW flow to NW flow	• W/SW flow to NW flow	• W/SW to NW flow
Pattern 4	• Easterly component	• Easterly component	• Easterly component
Pattern 5	• N/NW flow	• W/NW flow to SW flow	
Pattern 6			
Pattern 7			

From the original patterns, looked for variations within each level and pattern to gather more detailed pattern possibilities

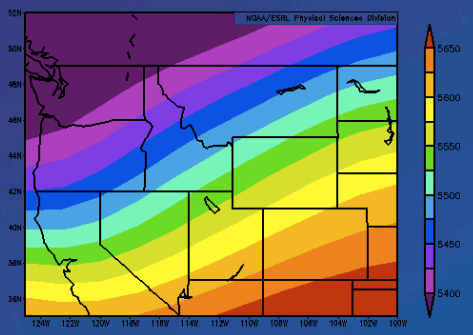
Things to consider…



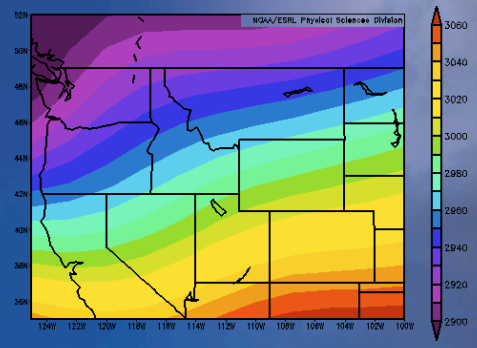
- Too few cases to make any official pattern recognition?
- Outlier cases
- Local, mesoscale and synoptic effects
- Current forecast models have better resolution

Pattern 1

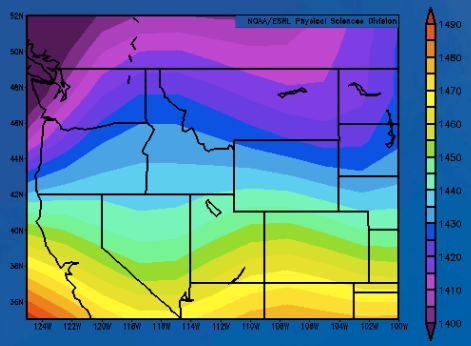
Southwest flow at 500mb/Northwest flow at 850mb



500mb



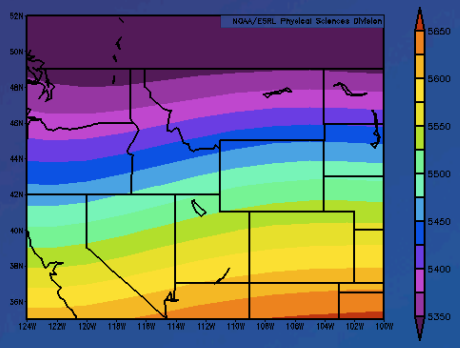
700mb



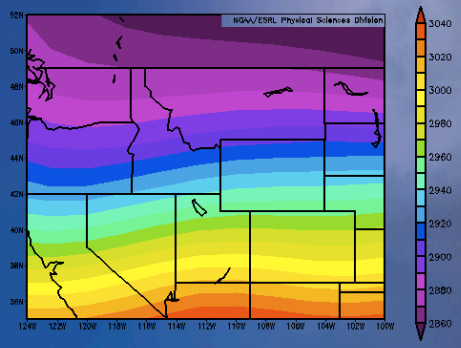
850mb

- Accounted for 5 out of 50 cases
- Predominant west and southwest flow at 500mb and 700mb
- Three cases indicated ≥7 inches of snow at KBZN over 48 hours
- Did not favor heavy snowfall at Bridger Bowl

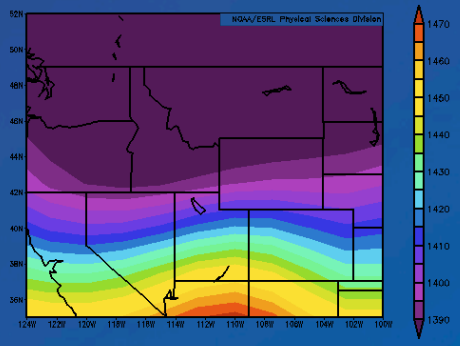
Pattern 5



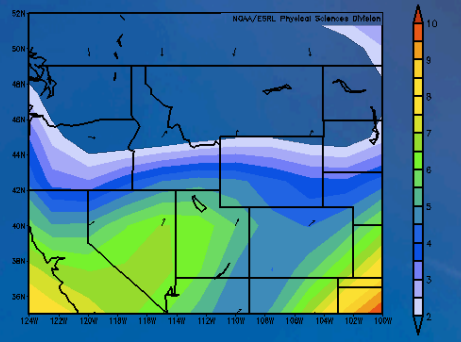
500mb



700mb



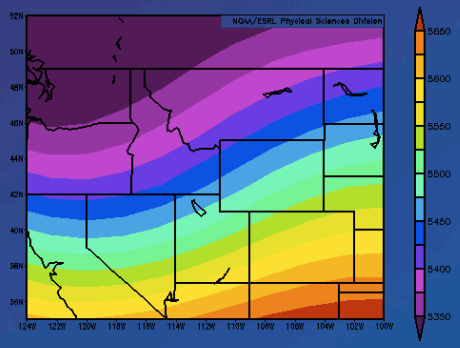
850mb



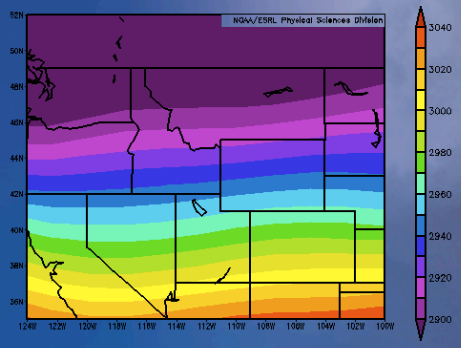
850mb winds

- Accounted for 12% of cases
- Predominant west and southwest flow at 500mb and 700mb
- Easterly winds at 850mb and occasionally 700mb
- 66.7% favored heavier snowfall at KBZN and ~45% for MSU-Bozeman
- Did not favor heavy snowfall at Bridger Bowl

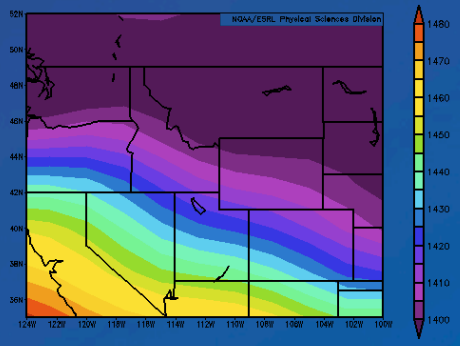
Pattern 9



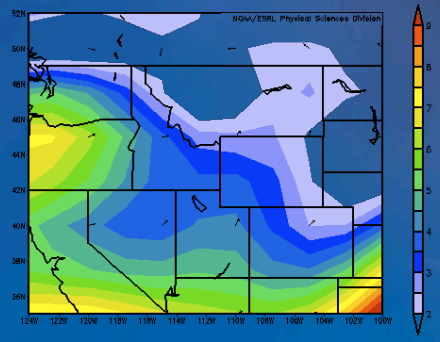
500mb



700mb



850mb

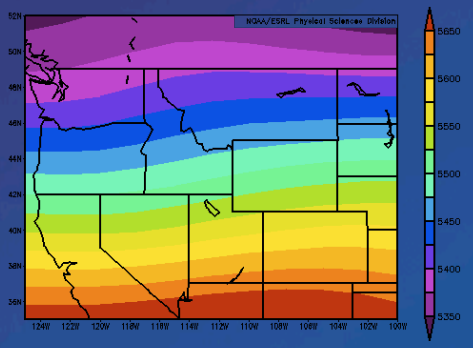


850mb winds

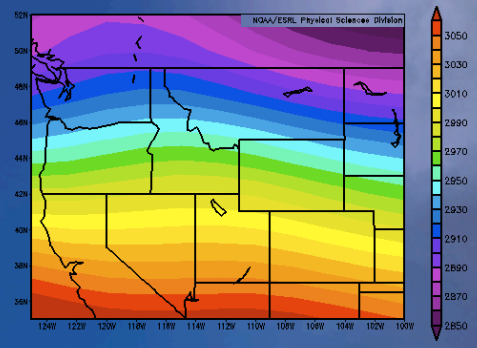
- Accounted for 4% of cases
- Predominant west and southwest flow at 500mb
- Southwest flow becomes northwest at 700mb with light easterly component winds at 850mb
- Favored light snowfall for KBZN and MSU-Bozeman
- Moderate snowfall for Bridger Bowl with northerly low-level component winds

Pattern 2

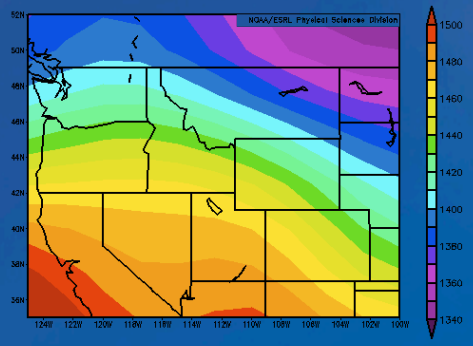
West-southwest flow at 500mb/Northwest flow at 700mb & 850mb



500mb



700mb

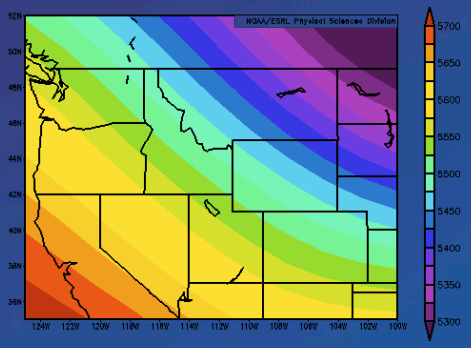


850mb

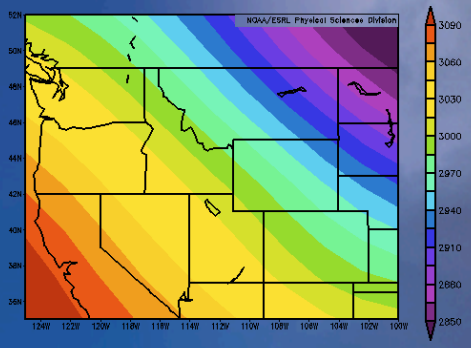
- Accounted for 6 out of 50 cases
- Reanalysis data Indicated upper-level trough moving into Pacific Northwest
- Snowfall at KBZN and MSU-Bozeman less than 5 inches over 48 hours
- Did favor moderate snowfall at Bridger Bowl (around 20-24 inches in 48 hours)

Pattern 3

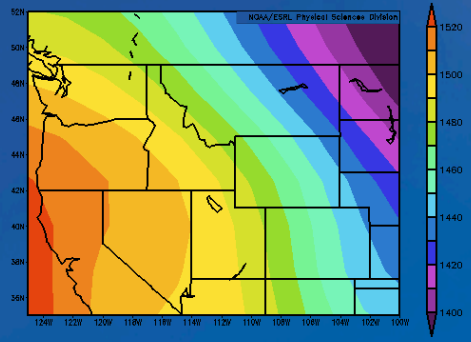
Northwest flow



500mb



700mb

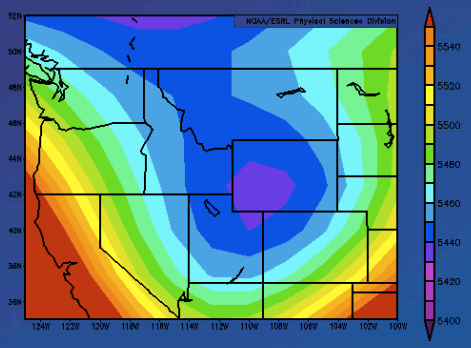


850mb

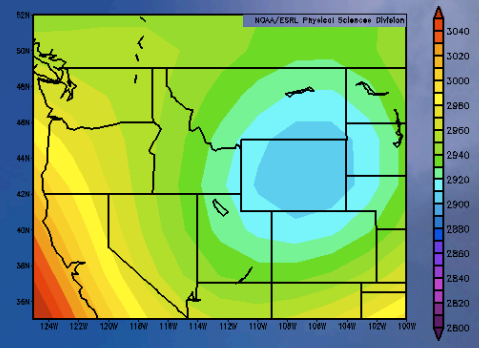
- Accounted for 9 out of 50 cases
- Predominant northwest flow at 500mb, 700mb and 850mb
- Five cases favored heavier snowfall at Bridger Bowl (≥24 inches over 48 hours)

Pattern 4

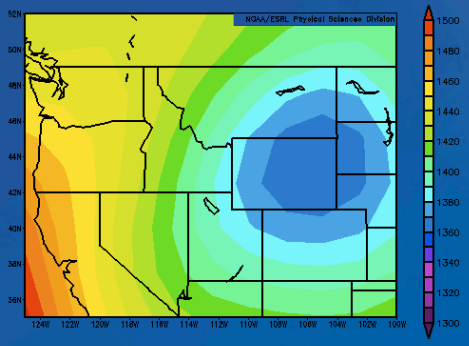
Easterly flow



500mb



700mb

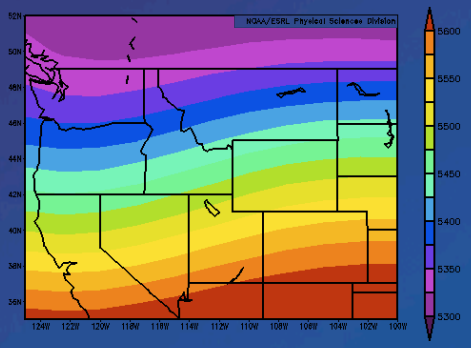


850mb

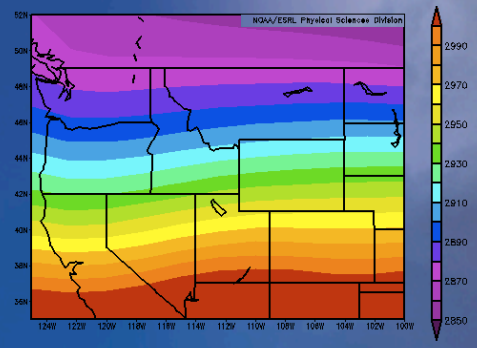
- Accounted for 3 cases – outliers?
- Predominant easterly component flow – lighter wind speeds
- Each case for MSU-Bozeman indicated moderate snowfall (≥10 inches in 48 hours)
- Did not favor heavy snowfall at KBZN or Bridger Bowl

Pattern 5

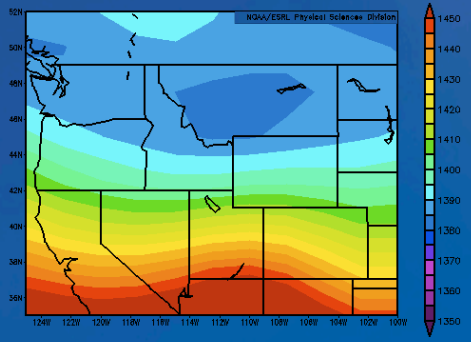
West-southwest flow



500mb



700mb

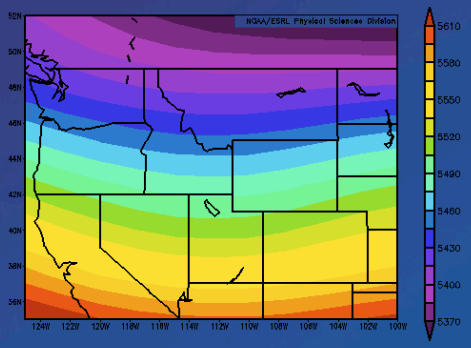


850mb

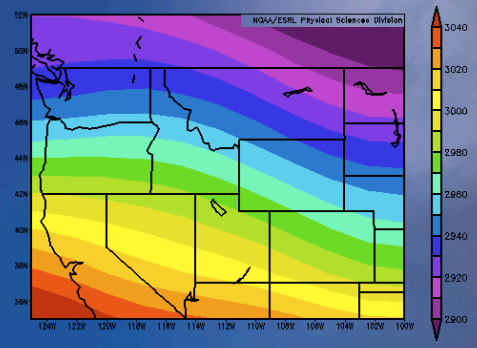
- Accounted for 8 out of 50 cases
- West-southwest flow at 500mb and 700mb
- Lower heights at 850mb – easterly low-level component?
- Did not favor heavy snowfall at MSU-Bozeman
- Two cases favored heavy snowfall at Bridger Bowl (≥24 inches over 48 hours) and four cases indicated >8 inches of snowfall over 48 hours at KBZN

Pattern 6

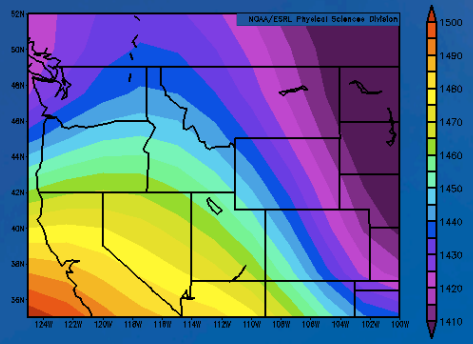
Westerly flow aloft/Northwest low-level flow



500mb



700mb

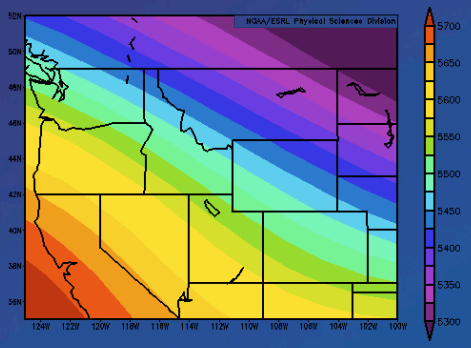


850mb

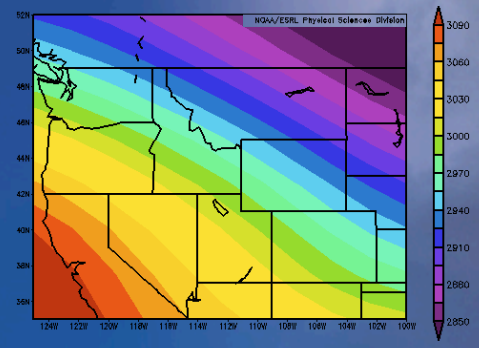
- Accounted for 7 out of 50 cases
- Predominant westerly flow at 500mb and 700mb
- No clear conclusion of heavy snowfall at any site

Pattern 7

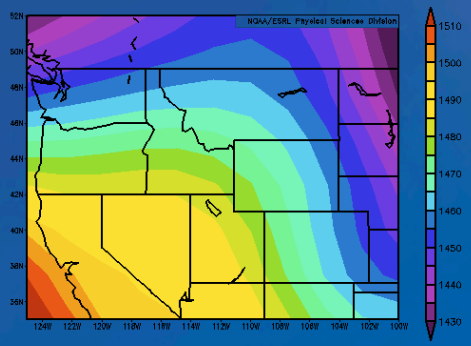
Northwest flow at 500mb & 700mb/Southwesterly flow at 850mb



500mb



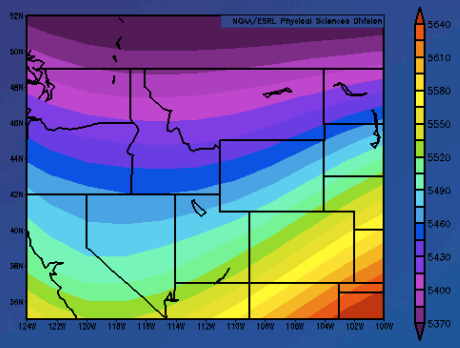
700mb



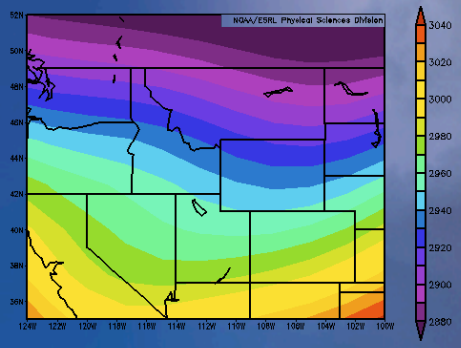
850mb

- Accounted for 10 out of 50 cases
- Predominant northwest flow at 500mb and 700mb
- West-southwest flow at 850mb
- Five cases favored heavy snowfall at Bridger Bowl (≥24 inches in 48 hours)

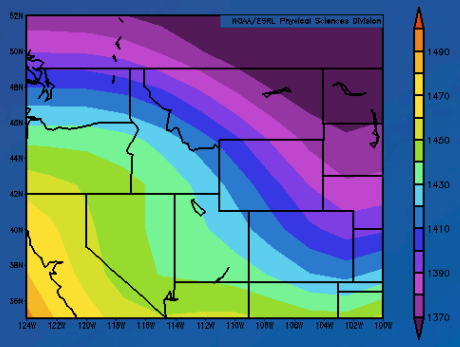
Pattern 10



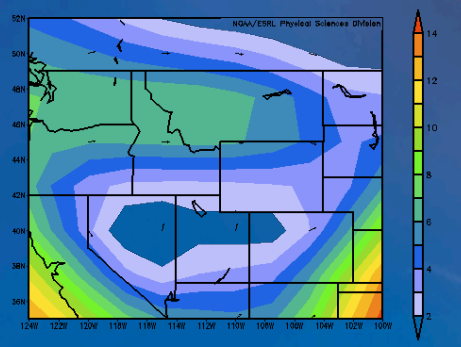
500mb



700mb

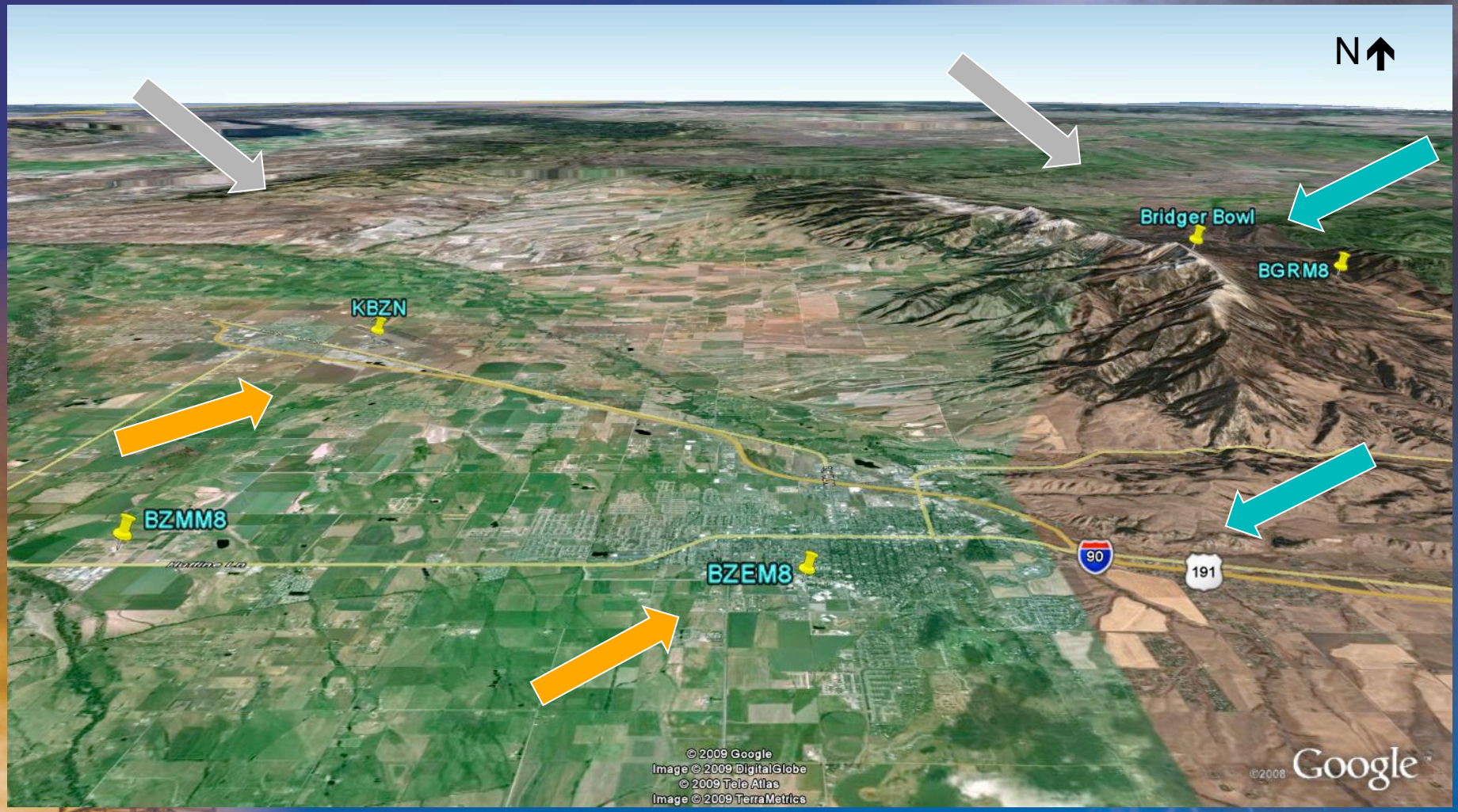


850mb



850mb winds

- Accounted for 4% of cases
- West-southwest flow becomes northwest at 500mb, 700mb and 850mb
- <20% favored moderate snowfall for MSU-Bozeman
- Did not favor heavy snowfall at KBZN or Bridger Bowl


N
Bridger Bowl
BGRM8
KBZN
BZMM8
BZEM8
90
191
© 2009 Google
Image © 2009 DigitalGlobe
© 2009 Tele Atlas
Image © 2009 TerraMetrics
©2008 Google

Other Research

- The GNFAC has also done research specific to Bridger Bowl to determine which patterns favor heavy snowfall in support of better avalanche forecasting
  - *"…as the trough in the western United States intensifies, a shortwave moving from the Pacific along the back side of the trough towards Bridger Bowl is important for the development of heavy snowfall…". (Birkeland, Karl W. and Mock, Gary J. from 'Atmospheric Circulation Patterns Associated with Heavy Snowfall Events, Bridger Bowl, Montana, U.S.A.')*

Conclusions

- Still too few cases and data to strongly support one pattern over another – more research needed for a complete data set
- Synoptic vs. mesoscale resolution – is this representative?
- Difficulty separating local, synoptic and mesoscale effects
- Need to consider intensity of upper-level low pressure, moisture availability and speed of storm systems
- How great of a factor do wind speeds aloft play into heavy snowfall amounts?

Conclusions (continued)

- Strong northwest flow can support heavier snowfall at both KBZN and Bridger Bowl…however for KBZN to receive heavier snowfall there should be a low-level southwest component
- What's next?
  - *Would like to see if these patterns apply to snowfall events over the last 10 years*
  - *Is the 850mb modeled wind data comparable to observed wind data at KBZN?*

Thank You for Listening!

- **References**

  - *Birkeland, Karl W. and Mock, Gary J. "Atmospheric Circulation Patterns Associated with Heavy Snowfall Events, Bridger Bowl, Montana, U.S.A." Mountain Research and Development, Vol. 16, No. 3 (1996) pp. 281-286*
  - *U.S. Department of Commerce | National Oceanic and Atmospheric Administration | Earth System Research Laboratory | Physical Sciences Division <http://www.esrl.noaa.gov/psd/data/composites/day/index.html>*
  - *NOAA NWS NCEP Reanalysis Data Display by NCEP HPC http://www.hpc.ncep.noaa.gov/ncepreanal/*
  - *Plymouth State University Weather Center <http://vortex.plymouth.edu/upairwx-r.html/>*